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A monthly survey of programs and findings of the International Geophysical Year and the International Geophysical Cooperation–1959 as related primarily to United States programs. The Bulletin *also reports on international programs in geophysics and space science that have grown out of the IGY, and on their results.*

Explorer X Magnetic-Field and Plasma-Probe Satellite

The National Aeronautics and Space Administration's Goddard Space Flight Center, at 10:17 am EST on March 25, 1961, launched a satellite intended to gather definitive information on the earth's magnetic field, on interplanetary magnetic fields, and on the way these fields affect and are affected by the clouds or streams of electrically charged particles, or plasma, thrown outward by eruptions on the surface of the sun. The 78-pound satellite (Fig. 1), named Explorer X (and designated 1961 Kappa for tracking), was launched from Cape Canaveral, Florida, by a Thor-Delta rocket. It was injected into a highly elliptical orbit approximately six minutes later.

Immediately following ascertainment that orbit had been achieved, notification was sent to COSPAR for dissemination to all COSPAR participants. Data obtained by Explorer X will be transmitted to COSPAR and will also be deposited in the IGY World Data Centers.

Orbit

The "window," or period during which the probe could be launched, was restricted to three hours per day on about ten days per month. Only within these restricted periods was it possible to program a trajectory providing the proper relative positions of earth, sun, moon, and payload, such that (i) solar noise would not distort or block out transmissions from the probe; (ii) the optical-aspect system would have proper "look" angles toward the sun, earth, and moon in order to determine the payload's orientation in space for correlation with transmitted data; and (iii) the payload would be in the proper orientation to detect and measure particles emitted from the sun.

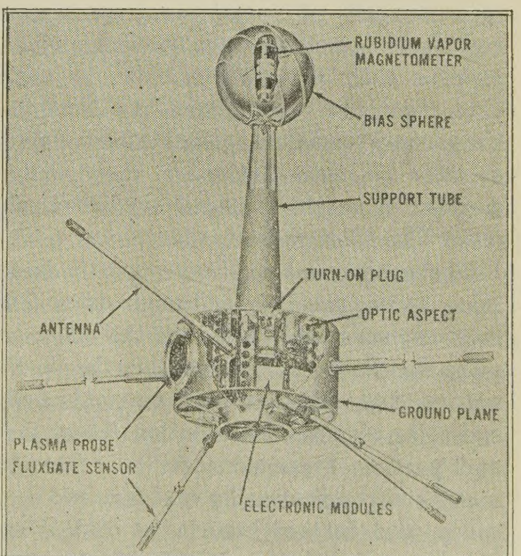

Fig. 1. *Explorer X (1961 Kappa) Magnetometer and Plasma-Probe Satellite, in Cut-Away View. From NASA photograph.*

The orbit calculated to satisfy these conditions, and to obtain representative data on magnetic fields and charged particles in interplanetary space, was a highly eccentric one with an inclination of 33°, apogee of over 100,000 statute miles and perigee of about 105 statute miles. (See Figure 2.) The orbit actually achieved was such that, about 59 hours after launch, Explorer X reached an apogee of about 145,000 statute miles at an azimuth of 140°–150° from the sun-earth direction. Perigee was estimated at about 100 statute miles.

Purpose of Experiment

While this flight was a continuation of scientific investigations made with earlier satellites and space probes, it also was a new effort in many respects. It was the first flight into deep space with a highly accurate rubidium-vapor magnetometer. This absolute instrument also makes possible measurements of hydromagnetic shock waves coming from the sun and impinging on the earth's magnetic field.

The plasma experiment was to obtain measurements of very-low-energy protons coming to the earth from the sun, and determine their direction of flow. In addition, the probe was designed to determine the geometry and strength of interplanetary or solar magnetic fields, and the distribution and strength of electric currents in the outer Van Allen radiation belt.

The experiment was expected to determine more precisely—through total-field measurements and studies of the effects of magnetic fields on charged particles—the nature of the interaction of magnetic fields and solar corpuscular radiation. These field and particle phenomena will characterize man's environment as he ventures into deep space, and further knowledge of this environment will make it possible to chart flight paths that pass through the least hostile regions of interplanetary space.

Instrumentation

The satellite and its instrumentation are shown in a cut-away view in Figure 1. The following is a description of the primary instrumental components.

Rubidium-Vapor Magnetometer: The heart of this payload is the 1.5 pound rubidium-vapor magnetometer, a relatively new, extremely sensitive and accurate instrument. The Explorer X model measures field intensities ranging from .01 to 7000 gammas. It is an absolute instrument—that is, its measurements depend only on fixed constants that do not require calibration.

The rate at which the outer Rb-87 electron revolves around its nucleus is known precisely and would produce a frequency of nearly 7 cycles per second in a weak magnetic field of 0.00001 gauss. The frequency is directly proportional to the field strength —i.e., the stronger the field, the higher the frequency.

This is the way the rubidium-vapor magnetometer works: Light from a small rubidium lamp passes through a filter, lens, and polarizer, and polarized light at a wave length of rubidium then passes into a cell containing rubidium vapor. The light is absorbed by those rubidium-87 atoms having a particular orientation in the cell. When this occurs, the cell becomes opaque to the passage of light, which is detected with a silicon photocell whose output is fed to an amplifier.

As the opaqueness exists for only one-half cycle of the spin of the rubidium atoms, the cell is alternately opaque and transparent at the spin frequency, which is determined by the strength of the magnetic field. This produces a fluctuating light at the photocell which is then amplified and fed back as a small alternating magnetic field, which produces an ordered alignment of the rubidium atoms such that the process will be self-continuing.

Fluxgate Magnetometers: The two flux-

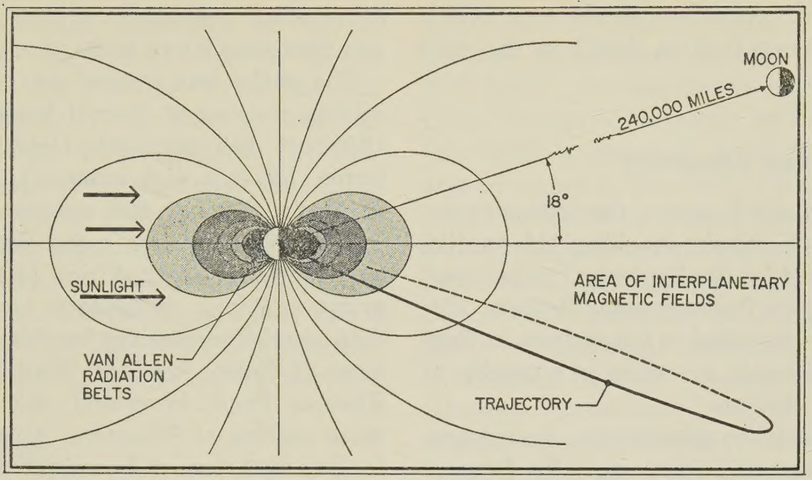

Fig. 2. *Planned Trajectory of Explorer X. The satellite's actual orbit was very close to that shown, providing the desired relative positions of earth, sun, moon, and satellite. NASA photograph.*

gate magnetometers, which weigh about one pound each, are considerably more sensitive than those flown in previous satellites. They are intended to measure fields from 0.5 to 25 gammas and to determine, primarily, the direction of weak magnetic fields. The fluxgate magnetometers are oriented on the payload at a specific angle, such that the spin of the payload makes it possible also to obtain total-field measurements.

Plasma Probe: This instrument, which weighs about 2.5 pounds, is designed to measure the density, direction, and bulk velocity of interplanetary plasma. Positive and negative particles enter the probe through a six-inch circular aperture and pass through a series of grids behind which there is a collector. Owing to this arrangement, the probe is sensitive only to protons with velocities ranging from 6 mi/sec to 1000 mi/sec.

Preliminary Results

Experimental data obtained by Explorer X were transmitted continuously to earth for 60 hours, slightly in excess of the nominal battery life of 55 hours. The scientists responsible for the magnetic field studies by Explorer X, were J. P. Heppner, T. L. Skillman, C. S. Scearce and N. F. Ness, of the Goddard Space Flight Center of NASA. The plasma experiment was conducted by H. S. Bridge, F. Scherb, and B. Rossi, of the Massachusetts Institute of Technology.

At the Forty-Second Annual Meeting of the American Geophysical Union, April 18–21, 1961, the experimenters reported on results indicated by an initial examination of the data. These included: (i) a finding that the interplanetary magnetic field was more intense than anticipated; (ii) detection of large, sudden changes, presumably shock waves, in the magnetic field; (iii) observation of field changes in space at the time of a sudden magnetic-storm commencement at the earth's surface; (iv) measurements of the number densities and velocities of low-energy protons; and (v) a finding that the plasma flux was received primarily from the direction of the sun. The fact that a class 3 solar flare, followed 28 hours later by a sudden commencement, occurred within the 60 hours of battery life

gave added importance to the data, which will be reported on in detail in the near future.

Tracking and Telemetry

A new ground system for telemetry reception and doppler-tracking information was designed for the Explorer X experiment by Goddard's Radio System Branch. This system was installed at the stations in England and Hawaii, as well as at a number of Minitrack stations.

Data from the experiments were transmitted to the earth by a specially designed 108-megacycle transmitter employing phase modulation, operating at 35% efficiency, and producing 5 to 6 watts of output power.

The probe was tracked by primary receiving stations at Jodrell Bank, England (250-foot dish antenna); Goldstone, California (85-foot dish antenna); Woomera, Australia (85-foot dish antenna); Hawaii (60-foot dish antenna); and Esselen Park, Johannesburg, South Africa (a 22-db yagi array antenna). Secondary tracking and data acquisition stations for this experiment were at Quito, Ecuador; Santiago, Chile; Blossom Point, Maryland; and the Minitrack station at Woomera, Australia. The facility on Ascension Island provided tracking information.

Geophysics Research Board

The Geophysics Research Board (GRB) was established in 1960 by the President of the National Academy of Sciences, Detlev W. Bronk, in concert with the Governing Board of the Academy. This action was taken partly in response to a request from the International Council of Scientific Unions (ICSU), which had called upon all national science academies to establish a means for their cooperation with the International Geophysics Committee (CIG) of ICSU, and partly in response to expressions of interest by many members of the United States geophysical community. The American Geophysical Union, for example, strongly urged that the Board be established.

Discussions involving many geologists and geophysicists led Dr. Bronk to define the basic functions of GRB as follows: "(1) to effect participation by American scientists in the activities of the new International Committee on Geophysics of the International Council of Scientific Unions; and (2) to stimulate and encourage research interest in the United States in geophysics and related fields, particularly those of an interdisciplinary character. We would look to such a board also to avoid unnecessary duplication and insure full coordination of our several related efforts in these fields."

Membership of GRB

Inasmuch as the membership of CIG is partly made up of designated representatives of the various international unions concerned with geophysics in the broad sense, it was felt that the GRB composition should reflect both the various Academy committees concerned with geophysical problems and the other Academy committees that are counterpart to international committees, thus bringing together the geophysical interests of the Academy and providing an approximate parallel to the CIG.

The membership of GRB is as follows: L. V. Berkner (Space Science Board); Harrison S. Brown (Committee on Oceanography); Michael Ference, Jr. (Committee on Atmospheric Sciences); L. M. Gould (Committee on Polar Research); H. G. Booker (US National Committee for the Interna-

tional Scientific Radio Union); Joseph Kaplan (US National Committee for the International Geophysical Year); M. A. Pomerantz (US National Committee for the International Union for Pure and Applied Physics); W. O. Roberts (US National Committee for the International Astronomical Union); G. P. Woollard (US National Committee for the International Union of Geodesy and Geophysics); and two members-at-large: M. A. Tuve, who is Chairman of GRB, and F. W. Reichelderfer; Hugh Odishaw is the Executive Director.

Panels of GRB

In order to consider specific international programs now being promulgated by CIG, the GRB established four panels, as follows:

World Magnetic Survey (WMS): This panel is charged with considering the international recommendations on the WMS (a description of the WMS will appear in a forthcoming issue of the *Bulletin*) and to make recommendations for United States participation in the program. Technical supervision of the WMS is under the International Association of Geomagnetism and Aeronomy (IAGA) while international coordination is being handled by the CIG. The WMS period has been set for 1964–65, when the minimum of solar activity is expected to occur. Measurements being made now will also be useful for WMS as they can be reduced to epoch 1965 through knowledge of the rate of change of the magnetic-field elements.

E. H. Vestine (RAND Corporation) is Chairman of the Panel; its members are L. R. Alldredge (US Coast and Geodetic Survey), J. R. Balsley (US Geological Survey), B. C. Byrnes (US Navy Hydrographic Office), J. P. Heppner (National Aeronautics and Space Administration), J. H. Nelson (US Coast and Geodetic Survey), and Victor Vacquier (Scripps Institution of Oceanography); Secretary, Stanley Ruttenberg (NAS).

International Year of the Quiet Sun (IQSY): This panel is studying the international recommendations for IQSY, and will make recommendations regarding United States participation in the program (the IQSY is discussed in greater detail in another report in this issue of the *Bulletin*).

M. A. Pomerantz (Bartol Research Foundation) is Chairman of the Panel; its members are R. Grant Athay (High Altitude Observatory, University of Colorado), C. T. Elvey (Geophysical Institute, University of Alaska), Herbert Friedman (US Naval Research Laboratory), R. A. Helliwell (Radioscience Laboratory, Stanford University), Joseph Kaplan (University of California at Los Angeles), Sadami Matsushita (High Altitude Observatory), Alan Maxwell (Radio Astronomy Observatory, Harvard University), Peter Meyer (Enrico Fermi Institute for Nuclear Studies, University of Chicago), H. V. Neher (California Institute of Technology), E. P. Ney (University of Minnesota), H. E. Newell, Jr. (National Aeronautics and Space Administration), J. A. Van Allen (State University of Iowa), A. H. Waynick (Pennsylvania State University); Secretary, Stanley Ruttenberg (NAS). Two meteorologists will be added to the Panel.

International Exchange of Scientific Data: This panel is concerned with the CIG recommendations regarding the exchange of geophysical data: these involve, first, completion of the IGY/IGC exchange; second, examination of the needs for the period 1960–63; and third, planning for exchange of data accumulated during the WMS and IQSY, 1964–65. The CIG itself now has underway a critical review of the data exchange, discipline-by-discipline, with a view toward eliminating exchange of data that are no longer useful and including data from new types of observations or experiments. The CIG is looking to its reporters in each geophysical discipline and to the various international unions for advice and recommendations on data exchange.

This GRB panel is seeking the opinions of United States scientists on what might be the most useful exchanges to carry out, and is also studying the structure of World Data Center A in terms of how the various sub-centers can best complete their IGY/IGC responsibilities and carry out recommendations that CIG will develop for data exchange in the coming years.

A. H. Shapley (CRPL, National Bureau of Standards) is Chairman of the Panel; its members are L. R. Alldredge (US Coast and Geodetic Survey), A. J. Dessler (Lockheed Aircraft Corporation), J. P. Heppner (NASA), J. A. Lockwood (University of New Hampshire), Hugh Odishaw (National Academy of Sciences), Harry Wexler (US Weather Bureau) and R. W. Porter (General Electric Company); Secretary, Pembroke J. Hart (NAS).

Solid Earth Problems: This panel was organized in cooperation with the Earth Sciences division of the Academy, partly in response to the CIG proposal for an international program on the upper mantle of the earth (this program will be described in a future issue of the *Bulletin*), and partly in recognition of the opportunity that has developed in recent years to advance substantially our understanding of the nature of the solid earth. The Panel consists of two working groups.

G. P. Woollard (University of Wisconsin) is Chairman of Working Group 1; its members are L. T. Aldrich (Department of Terrestrial Magnetism, Carnegie Institution of Washington), Francis Birch (Harvard University), James Gilluly (US Geological Survey), H. H. Hess (Princeton University), H. L. James (US Geological Survey), Leon Knopoff (University of California at Los Angeles), Walter Munk (Scripps Institution of Oceanography), J. E. Oliver (Lamont Geological Observatory), Frank Press (California Institute of Technology), and John Verhoogen (University of California, Berkeley); Secretary, Linn Hoover (NAS).

H. S. Yoder, Jr. (Geophysical Laboratory, Carnegie Institution of Washington) is Chairman of Working Group 2; its members are Allen Cox (US Geological Survey), W. H. Diment (US Geological Survey), James Dorman (Lamont Geological Observatory), C. L. Drake (Lamont Geological Observatory), R. A. Haubrich (Scripps Institution of Oceanography), J. H. Healy (California Institute of Technology), Robert Meyer (University of Wisconsin), T. H. McCulloh (University of California, Riverside), John Steinhart (Department of Terrestrial Magnetism, Carnegie Institution of Washington), and J. B. Thompson (Harvard University); Secretary, Linn Hoover (NAS).

Origin of Subvisual Red Auroras

The following material is based on a more-detailed report by G. A. M. King and F. E. Roach, published in the March-April 1961 issue of the Journal of Research—D. Radio Propagation, *of the National Bureau of Standards.*

On the night of November 27–28, 1959, magnetic and auroral activity occurred over a large part of the United States. Visual observers, especially in the northwestern United States, reported auroral structure during the event, and, in particular, bright auroral activity with red in the northern sky was seen from Boulder, Colorado, at about 0600 UT.

Instrumental coverage was excellent, and included (1) all-sky camera observations; (2) photometric observations of the green (5577 A) and the red (6300 A) auroral lines at three stations in the southwestern United States; (3) ionospheric soundings,

with special recordings near Boulder in the low-frequency range (50 kc/s to 2 mc/s); and (4) measurement of fluxes of high-energy particles in the outer Van Allen zone during several passes of the Explorer VII satellite.

This report discusses the relationship between photometric observations of a subvisual red arc and ionospheric soundings. The authors hypothesize that the red emission is due to enhanced ionospheric recombination; they draw semi-quantitative support for this hypothesis from the observational data.

(*Bulletin No. 36* describes the subvisual monochromatic red arcs and discusses some early observations of them made during the IGY; *Bulletin No. 45* reports on correlations between photometric, visual, and satellite observations of both visual and subvisual auroral activity and of changes in the Van Allen radiation belt during the November 1959 event discussed in the present report.)

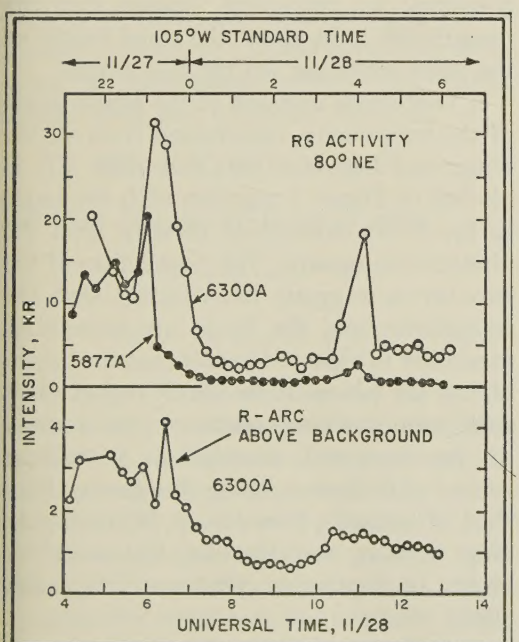

Fig. 3. *Intensity Changes in Visual (RG) and Subvisual (R) Auroral Activity during the Night of November 27–28, 1959. The RG activity was near northeast horizon, as seen from Fritz Peak, while the R-arc was higher in the sky (as shown in Figure 4).*

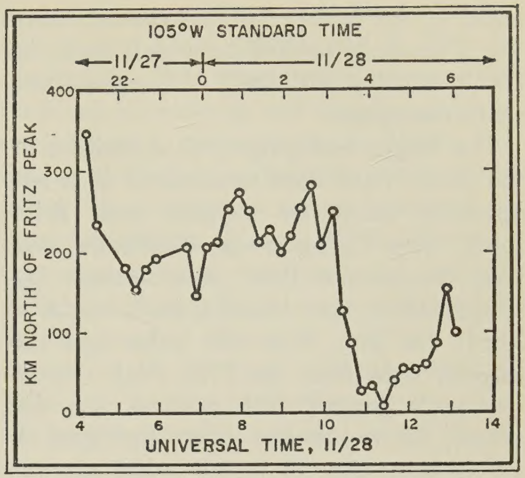

Fig. 4. *Position of R-Arc Relative to Fritz Peak on November 27–28, 1959. Assumed height of arc was 400 km.*

Photometric Observations

Photometric observations were made at Fritz Peak, Colorado, from 0410 UT to 1310 UT (9:10 pm-6:10 am local time), November 27–28, 1959, in three wave lengths, 5577 A [OI], 6300 A [OI], and 5893 A [NaI]. The forbidden oxygen radiations (5577 A and 6300 A) were active throughout the night. Two classes of activity occurred, and for convenience they are classified as follows: (1) *RG,* in which both the red (6300 A) and the green (5577 A) emissions are enhanced in intensity; (2) *R,* in which the emission forms an arc selectively enhanced in the red and with no apparent increase in the intensity of the green emission. It is tempting to think of *RG* as regular auroral activity, since both the red and green lines are characteristic features of auroras in general.

On this particular night, the *RG* activity covered a wide range of intensity (see Fig. 3), while the *R* activity went through slow and ponderous changes. The general impression from Figure 3 is that after 0700 UT, when the *R* data were no longer contami-

nated by the strong *RG* background, there was a tendency toward monotonic decay in the *R* activity until 0925 UT, when there was a resurgence.

The height and geographical position of the *R*-arc have been determined in a cooperative study by workers from Fritz Peak, from Cactus Peak, California, and from Sacramento Peak, New Mexico. By triangulation, they found a mean height of about 400 km. With this value and the angular data from the Fritz Peak records the arc's geographical position was deduced; the results are shown in Figure 4. At the same time, its width in latitude was determined to be about 500–600 km.

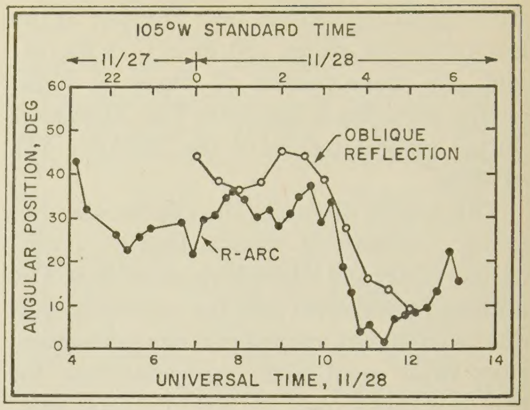

Fig. 6. *Angular Positions of R-Arc and Oblique Radio Echo Observed on November 27–28, 1959. It is thought that the oblique echo was reflected from a large irregularity in the F layer of the ionosphere at some distance from the station.*

Ionospheric Data

Ionospheric records were taken half-hourly at Boulder, 26 km from Fritz Peak. Figure 5 shows diagrammatically the salient features of the ordinary-wave reflections shown in the ionogram for 0730 UT.

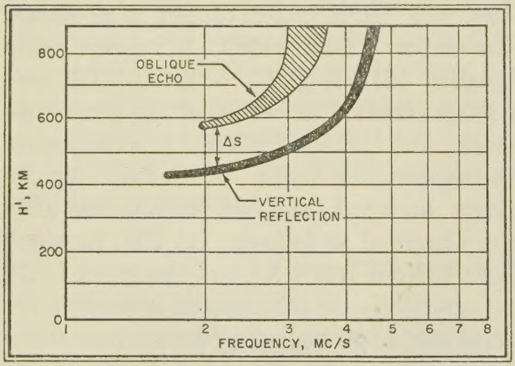

Fig. 5. *Diagram Showing Essential Features of Ionogram for 0730 UT, November 28, 1959, at Boulder, Colorado.*

A conspicuous feature of this ionogram is the spread echo above the main trace. As the F region totally reflects all waves traveling vertically in this frequency range, it is not possible for the spread echo to be overhead at a greater height than the normal F layer; therefore, the spread trace must be due to echoes received obliquely from a large irregularity in the F layer at some distance from the observing station. Further considerations, based on the conditions necessary for reflections, suggest that the irregularity is at about the same height as the layer reflecting the vertical echoes.

A very crude measure of the zenith angle of the irregularity, determined from all the ionograms between 0700 and 1200 UT, is plotted in Figure 6 together with the angle to the *R*-arc determined directly from the photometric records. The parallelism of the two curves suggests immediately that the irregularity and the *R*-arc are associated, especially in view of the fact that the height of the arc places it in the F region. This conclusion has been reinforced by a study of the temporal association of oblique echoes and *R*-arcs, using ionograms from Fort Monmouth, New Jersey, White Sands, New Mexico, and Boulder, Colorado, for nights in September 1957 and December 1959.

An important observation that can be made from Figure 5 is that the electron density in the irregularity is *lower* than in the overhead trace. In other words, the *R*-arc is associated with a local *decrease* in the ionization of the F region.

Relationship of the Red Emission to Ionospheric Recombination

In order to understand the origin of the red arcs, four observational facts must be explained; they are: (1) the occurrence of the *R*-arc after the main phase of a magnetic disturbance; (2) the steady change of intensity with time; (3) the strong emission of the red lines of atomic oxygen without measurable emission of the green oxygen line; and (4) the association of the *R*-arc with a local decrease in the ionization of the F region.

In the normal process of recombination in the ionosphere, electrons are produced during the daylight hours by photo-ionization of atomic oxygen, as follows:

$$O + hv \rightarrow O^+ + e.$$

As the reverse process of radiative recombination is extremely slow, the removal of electrons, both by day and by night, occurs through a two-step process involving, first, atom-ion interchange between the ionized oxygen atom and molecular nitrogen,

$$O^+ + N_2 \rightarrow NO^+ + N,$$

and then dissociative recombination,

$$NO^+ + e \rightarrow N^* + O$$

or

$$NO^+ + e \rightarrow N + O^*.$$

(The asterisk indicates that the particle is in an excited, or metastable, state but carries no electric charge.) Similar reactions involving molecular oxygen appear to be unimportant for the present purpose.

The second-step equation gives a relationship between recombination and upper-atmospheric emissions; the products of the recombination are excited atoms of nitrogen or oxygen, and when they decay to the ground states they emit characteristic radiations at 5199 A [NI] and 6300 A (and 6364 A) [OI].

If the distributions with height of both the electrons involved and the molecular nitrogen (N_2) are known, and if NO^+ is assumed to be in equilibrium between the atom-ion interchange and the dissociative-recombination reactions shown above, the rate of electron recombination can be computed. The exothermic energy balance (i.e., involving release of heat) of the dissociative-recombination reaction is 2.7 electron volts, which is sufficient to provide either an NI (neutral nitrogen) quantum (2.36 ev) or an OI (neutral oxygen) quantum (1.96 ev), but not both. Since precise data are lacking on the relative probability of the two variations of the dissociative-recombination reaction shown above, it is assumed that one OI quantum is emitted for every two recombinations.

Applying this theory to the calculation of the red emission on a "quiet" night, a rate of 10^{-4}/sec at 300 km was assumed for the atom-ion interchange reaction, and a rate coefficient of $2 \times 10^{-8}/\text{cm}^3/\text{sec}$ was adopted for the dissociative recombination reaction. Figure 7 compares the electron-density profile and the deduced 6300 A emission profile for the ionogram taken at 0730 UT, November 19, 1958. The integrated emission intensity of 28 rayleighs agrees well with previously observed values for quiet nights, and, in fact, D. Barbier obtained a value of 30 rayleighs for 0700 UT on the same night at the Haute Provence Observatory, France. (A weak, or faint, visual aurora in 6300 A radiation would have an intensity of at least 6000 rayleighs.) The height of the night airglow, at 6300 A, has not yet been measured, but available evidence places it in the F region (above about 170 km) of the ionosphere. In this example, a height of 260 km was deduced for the maximum emission.

To determine whether the same theory could explain the *R*-arc on the night of November 28, 1959, a direct comparison can be made between the theory and uncorrected observations. It is assumed that the abnormally great brilliance of the *R*-arc

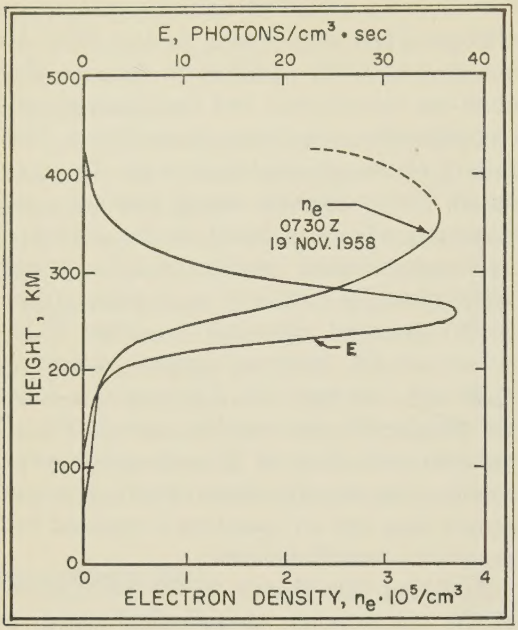

Fig. 7. *Profiles of Electron Density and 6300 A Emission under Quiet Conditions, 0730 UT, November 19, 1958.*

is due to enhanced recombination: i.e., that β, the rate-coefficient of atom-ion interchange between O^+ and N_2 for any density of N_2, is larger than its normal value such that the calculated emission agrees with the observed emission. The test of the theory, then, is based on comparison of the predicted and the observed heights of maximum emission.

For the electron-density profile at 0730 UT, November 28, 1959, almost perfect agreement is reached if, at a height of 300 km, $\beta = 10^{-1}$/sec. The electron-density profile and the emission profile are shown together in Figure 8. In a comparison of all of the five times on this date for which studies were made, the nearest approach to agreement also occurs when β_{300} is about 10^{-1}/sec. The effect of varying the rate coefficient for dissociative recombination between 10^{-8} and 10^{-7} cm^3/sec was studied, and 2×10^{-8} gave the best over-all agreement.

Reason for Increased Recombination

The rate of recombination required to give agreement between the theory and the observations is 1000 times the normal rate. This factor is so large that, in spite of the fair success of the theory, one must ask if it is reasonable.

The recombination rate, β, is proportional to $[N_2]$. Normally, at 300 km, $[N_2]$ makes up about one-thirtieth of the total number of atmospheric particles; this figure is based on a diffusion level of 105 km, which is in agreement with rocket observations. However, during auroral activity the atmosphere is heated by the influx of energetic particles. Direct evidence of this has recently been provided by T. M. Mulyarchik, who measured the temperature of the region emitting the 6300 A OI line; he found that the temperature increased with the brightness of the display.

Under normal conditions, the F region is hotter than the E region. Most of the energy of the aurora is set free in the E region, however, and if the increase in F-region temperature is due to conduction of heat from the E region, the normal temperature gradient would have to be reversed. This would call for a very great rise in the E-region temperature, and consequent great changes in atmosphere densities at all higher levels. Another consequence of interest here is the mixing caused by this reversal of the temperature gradient; this mixing raises the diffusion level and increases the fractional molecular concentration at higher levels. Thus, during and after auroral activity, we would expect to find a great increase in $[N_2]$ at F-region heights, and a factor of 1000 does not seem unreasonable.

Three other facts deserve mention in this respect. The first is that the electron-density profiles on November 28, 1959, are consistent with atmospheric scale heights in the F region 1½ times normal. Next, satellite drag data indicate an increase in

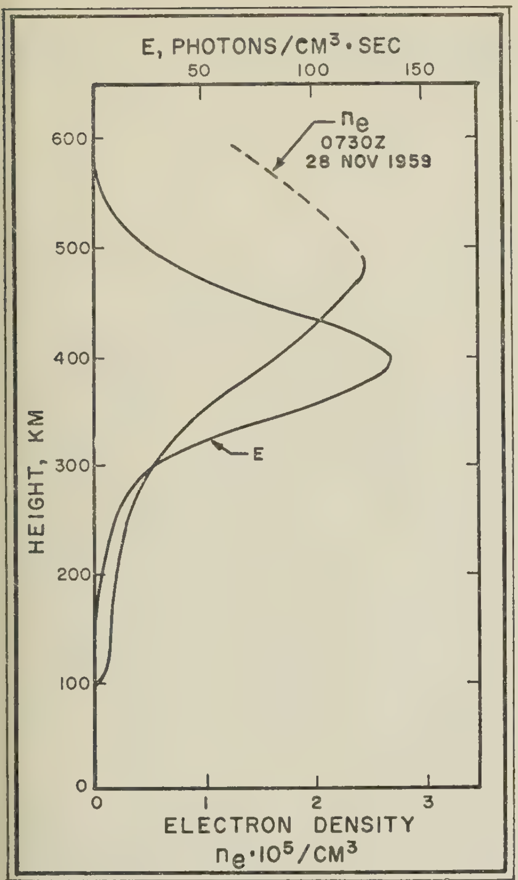

Fig. 8. *Profiles of Electron Density and 6300 A Emission on Night of November 28, 1959 (0730 UT), under Conditions of Auroral Activity.*

atmospheric densities at times of magnetic storms. Finally, E. A. Lytle and D. M. Hunten report that at dawn after an active aurora the N_2^+ emission was very greatly enhanced; while they explain this simply in terms of resonance scattering from N_2^+ ions generated by the aurora, it seems to the NBS investigators more likely, in view of the rapid recombination of N_2^+, that the ions were generated by solar ultra-violet light, and that the difference between this and normal dawn lies in the increased [N_2].

Further Discussion

Accepting the ideas of the last section, it must be asked what effect such a large change in the atmosphere would have on the computation of 6300 A emission according to the theory outlined previously; clearly, the [N_2] profile should not be derived in the simple manner used for quiet-night conditions. A trial calculation, based on scale heights greater by a factor of 1½ than those adopted previously (a preliminary model atmosphere computed by H. K. Kallmann and M. L. Juncosa on the basis of rocket and satellite data) shows that the emission profile is thickened, but that the height of maximum emission is not greatly altered; more important, however, is that the value of β_{300} needed to give the observed emission is decreased to only 400 times the normal value. As mixing also increases the effective scale height of [N_2^+], it is likely that on the night of November 27–28, 1959, the increase in β_{300} was much less than the 1000 times deduced earlier. The data do not justify a more complete analysis to determine the increase precisely.

Summary

To explain the origin of subvisual monochromatic (6300 A) red auroral arcs, the NBS investigators have submitted a hypothesis based on the excitation in the upper atmosphere of the oxygen atom to the ^1D energy state. The proposed mechanism involves (1) an atom-ion interchange in which O^+ and N_2 go to NO^+ and N, and (2) a dissociative recombination in which NO^+ and an electron yield excited atomic nitrogen or oxygen. The dissociative recombination is sufficiently exothermic (2.72 ev) to excite the oxygen atom to the ^1D energy state (1.96 ev) but not to the more-energetic ^1S state (4.16 ev).

To account for the strong emission of [OI] at 6300 A in the form of arcs on the equatorward side of general auroral activity, it is hypothesized that during an aurora the rate of the atom-ion interchange is increased by a large increase in the density of molecular nitrogen at F-region

heights as a consequence of heating of the atmosphere below and subsequent vertical mixing. The predictions of the hypothesis are in agreement with the observed height and intensity of the R-arc on the night of November 27–28, 1959.

International Year of the Quiet Sun

Solar and geophysical studies during IGY/IGC advanced our understanding of the many phenomena in the earth's atmosphere and in near space that are influenced by solar disturbances, and uncovered many new features of the atmosphere and of solar-terrestrial couplings. The success of the IGY/IGC program led IGY scientists to continue, on a less formal basis, many upper-atmosphere and solar observations. It was thought that most of them should extend at least through the waning portion of the solar cycle. In addition, the suggestion was made that certain types of observations should be repeated in a "little IGY," during the time of minimum solar activity so that some solar-terrestrial couplings at times of both maximum and minimum solar activity could be compared.

As a result of these views, a program at first called "The Solar Activity Minimum Program" was suggested. At an informal meeting of the International Committee on Geophysics (CIG) of ICSU, held at the time of the XIIth General Assembly of the IUGG, in Helsinki, August 1960, this program was discussed and a working group appointed to bring together the viewpoints of specialists in the upper-atmosphere and solar disciplines.

At the last meeting of the CIG, in Paris, January 1961, this program was discussed further and officially adopted as a CIG sponsored international program. The name "International Year of the Quiet Sun," or IQSY, was adopted and, upon the advice of the solar experts concerning the probable time of occurrence of solar minimum, the period April 1964 through December 1965 was designated.

The CIG working group emphasized that IQSY "is not to be regarded merely as a smaller scale repetition of the IGY but it is intended that full advantage shall be taken of the new knowledge of solar terrestrial relationship gained during the IGY and also of the improved and new techniques for geophysical research which have been, and will be developed in the intervening years."

It is expected that certain types of IGY synoptic programs will be repeated, though probably with less extensive geographical coverage than during IGY. In many fields, new experiments are being suggested stemming from new knowledge gained from the IGY and also from the fact that certain experiments and observations will be possible that could not have been made during the maximum portion of the cycle.

Preliminary International Program Recommendations

Based on the preliminary discussions at the informal meeting of CIG in Helsinki, the work of the various discipline reporters, and advice from some of the scientific unions interested in geophysical work, a preliminary statement of the IQSY program was developed at the Paris meeting, which may be summarized as follows:

World Days: As during the IGY, there will be an International Geophysical Cal-

endar with some Regular World Days and Intervals selected in advance. There will also be Alerts and Special World Intervals, as during IGY, to take full advantage of any important solar disturbance that should occur. It is expected that there will also be a rapid interchange of solar geophysical data among interested workers, as was done during IGY. (*Bulletin Nos. 42* and *47* report, respectively, on the most recent International Geophysical Calendar and most recent plan for World Days.)

Solar Activity: One of the key programs of IQSY will be a global solar patrol of the type that was instrumental in the success of the IGY. This program is important not only from the point of view of upper-atmosphere and space studies related to solar disturbances, but for an understanding of the sun itself. The quiet sun forms the easiest starting point for theoretical studies and provides an opportunity to investigate individual disturbances that are often far more complex near the time of solar maximum. Visual photographic and radio patrols will provide data for the issuance of Alerts and SWI and for rapid interchange among workers.

CIG suggested that the Solar Activity Data Centers should undertake to review the data they receive and offer comments to the collectors with a view to achieving greater uniformity in the reporting of solar data. Rocket and satellite techniques should increase the amount of solar data available. Recommendations were also made with reference to improving the services of the *Quarterly Bulletin of Solar Activity* and to expanding participation in the work of preparing daily solar maps.

Geomagnetism: Recommendations were made to continue the observation of time variations of the geomagnetic field and of earth currents. It was suggested that the present network of stations should be supplemented by additional locations, in particular in the auroral zones (near about 70° N and S geomagnetic latitude) and poleward from them, where geomagnetic activity responds clearly to weak solar corpuscular radiation. Rapid-run variometers should be installed to record the details of magnetic storms, which will undoubtedly be less frequent than during IGY, and perhaps less complex, and hence may offer a better possibility of understanding their morphology.

Aurora: During sunspot minimum the aurora is greatly changed from that of sunspot maximum. There are still auroras almost every night in the auroral zones but they do not develop and spread southward as so often happens during periods of sunspot maximum, such as the IGY; there will probably be very little auroral activity observed at latitudes much lower than the auroral zones.

A much smaller network of stations than for the IGY should serve to monitor the occurrence of aurora during the IQSY, but it is expected that many special experiments will be undertaken concerning the differences between auroral forms and activity at solar minimum as contrasted with maximum. One specific experiment that has been emphasized is establishment of comprehensive interdisciplinary observing programs at pairs of magnetic conjugate points. The observations should include a full complement of optical auroral observations, radar observations, ionospheric absorption studies, measurements of magnetic fluctuations ranging from the standard type into the sub-audio frequencies, vertical-incidence ionosoundings, and cosmic-ray intensity measurements.

Airglow: Airglow observations will be particularly important during solar minimum because of the absence of auroral contamination outside the auroral zones. Consequently, airglow studies for IQSY may represent an increase over those of the IGY.

The CIG group made a number of recommendations concerning the specific airglow emissions to be studied, and recommended that chains of stations be installed to study

the OH emission bands and the NA-D twilight emission. It was suggested that aircraft be used for the study of the geographical distribution of the 6300 Å arcs (these arcs are discussed in another report in this issue of the *Bulletin*) and other airglow features.

Ionosphere: It was recommended that synoptic-type programs be repeated for comparison with IGY observations, although it was recognized that it may not be necessary for the IQSY station network to be as complete as that of the IGY in order to determine and study the solar-cycle effects. New techniques should be exploited to follow up new knowledge of the ionosphere gained during and since the IGY, with emphasis on ionospheric studies for which change in solar activity is an important factor.

A number of important ionospheric-physics studies of problems that are mostly unsolved were listed for emphasis during IQSY, including, for example, sounding of the upper side of the F region by rockets and satellites; investigation of geomagnetic control of the ionosphere; investigation of absorption processes in the lower ionosphere; investigation of dynamic processes; continuation of the study of the physics and chemistry of formation and maintenance of regular ionospheric layers; investigation of the state and development of the ionosphere over the polar caps; and study of irregularities in electron distribution in the very high ionosphere and exosphere.

Cosmic Rays: It was recommended that the international network of cosmic-ray stations should continue, through the IQSY period, regular observations on the level of those of the IGY. Studies of low-energy primary cosmic rays and of the cosmic-ray equator may be particularly fruitful during solar minimum. The solar minimum period should also provide opportunity to study sidereal cosmic-ray variations and, since the solar variation of primary cosmic-ray intensity is expected to be small during the IQSY, there is an excellent opportunity to investigate atmospheric effects on cosmic-ray intensities at ground level.

Investigation of the great belts of geomagnetically trapped radiation surrounding the earth will be of considerable importance, particularly with regard to determination of the positions of the belts in space and of the nature and energy distributions of the particles constituting these belts.

Space Research: The CIG looks to the Committee on Space Research, COSPAR, for assistance in developing recommended programs for rockets, satellites, and space probes during IQSY. (These questions were considered at the meeting of COSPAR, in Florence, Italy, April 1961, and a series of recommendations was developed that include observations of magnetic fields and particles in interplanetary space and exploration of current systems in the earth's atmosphere and beyond.)

In addition, the CIG suggested for inclusion in the IQSY, studies of the intensity and polarization of the zodiacal light in order to determine the distribution of dust and other material in interplanetary space in the neighborhood of the earth; measurements of magnetic-field intensities and variations in interplanetary space; and studies of phenomena in the terrestrial atmosphere associated with hydromagnetic waves.

Aeronomy: It is desirable to measure many parameters in the upper atmosphere, including pressure, density, concentration of various constituents, identification and concentration of positive and negative ions, and electron densities. New techniques, it was suggested, must be introduced to obtain vertical distribution of mean molecular mass and mean molecular temperature. Spectral observations of the extreme ultraviolet radiation of the sun should be included so as to obtain complete solar data.

Among the specific recommendations for inclusion among IQSY programs are meas-

urement of the absolute energy values and spectral distribution of solar radiation; of atmospheric absorption of solar radiations for various spectral ranges; and of the specific absorption of various constituents. To determine the real solar significance of the various solar indices, it was recommended that solar ultraviolet spectra be obtained by rockets up to the altitude of zero optical depth and that absolute intensities of lines be measured through the entire ultraviolet spectrum. To obtain the spectrum of the quiet sun for comparison with that during disturbed conditions, it was recommended that the sun's ultraviolet and X-ray spectra be monitored from satellites.

GRB Panel on IQSY

In order to provide a means for planning United States participation in the IQSY, a Panel on IQSY was established by the Geophysics Research Board (GRB) of the US National Academy of Sciences, as described in another report in this issue of the *Bulletin.* At its first meeting, in April 1961, GRB's Panel on IQSY endorsed the recommendations of the CIG as a basic guide for the international program, and recommended some extensions and modifications.

Meteorology: The Panel expressed a desire to include some meteorological studies in the IQSY program, and suggested that attention be given to various possibilities for special observations. It was recommended that two meteorologists be invited to join the Panel to ensure coverage of meteorological observations in the US program.

Timing of the Program: The Panel felt strongly that the IQSY should be planned so that observations would be well under way in advance of the arrival of solar minimum. It was pointed out that high-activity cycles tend to be shorter than average, and that the IGY cycle was the highest yet observed. It is therefore considered possible that the approaching solar minimum may occur earlier than expected. An advance-test year was proposed for 1963 so that as many observations as possible could be started as a safeguard should minimum occur early. This would also enhance the value of certain observations that should be made well in advance of minimum.

US-IQSY Programs: The GRB Panel discussed the specific program recommendations made by CIG and COSPAR, not only in terms of the international program but in terms of the interests of United States scientists as well. In order to develop the US program, the Panel feels it desirable to inform as wide a segment as possible of the US geophysical community, and to seek information on:

(i) Programs that might contribute to the objectives of the IQSY, but which are already definitely planned and expect to receive support during the IQSY period.

(ii) Additional programs that might be supported through regular channels.

(iii) Research programs or experiments that might be significant contributions to IQSY, but which are of such a nature that direct collaboration or coordination is required on an international level, or which are too large in magnitude for regular geophysical programs of the various support agencies.

The IQSY Panel is also considering possible contributions to the program by amateur groups, such as radio amateurs, auroral observers, and the various amateur satellite tracking groups active during the IGY. Suggestions on these matters would be welcomed by the Panel and should be addressed to the Secretary, IQSY Panel, Geophysics Research Board, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington 25, D. C.

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